

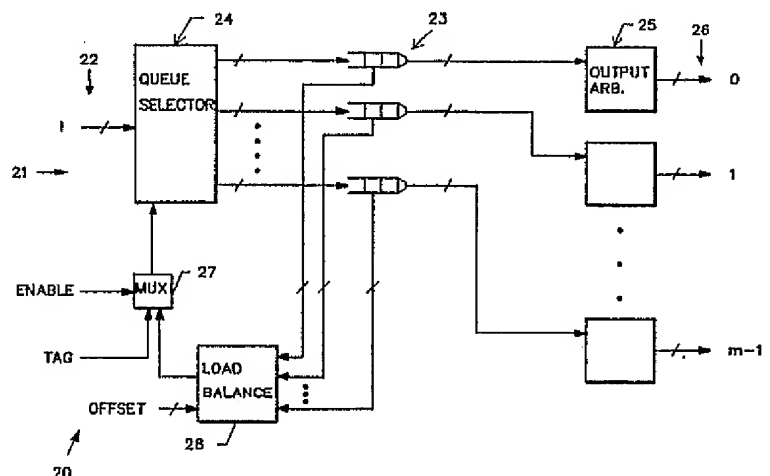
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(54) Title: LOAD BALANCING FOR PACKET SWITCHING NODES

(57) Abstract

A load balancing circuit arrangement for use with a packet switching node. The packet switching node processes applied data packets containing routing tag signals indicative of the output port destinations to which the data packets are addressed, and routes these packets to the identified output ports. The present invention a load balancing circuit coupled to the packet switching node which monitors the output port addresses of the applied data packets and monitors the number of data packets addressed to each of the output ports. The load balancing circuit is adapted to generate new routing tag signals identifying output port addresses which redistribute the output port load. The load balancing circuit arrangement in-



cludes a tag selection circuit coupled to the load balancing circuit and the packet switching node which selectively replaces the routing tag signals of the applied data packets with the new routing tag signals in order to redistribute and balance the output port load. The load balancing circuit comprises a minimum index circuit for generating the new routing tag signals and an adder circuit coupled thereto. The minimum index circuit combines the new routing tag signals with offset signals that modify the new routing tag signals in order to implement a predetermined output port priority scheme. The load balancing circuit arrangement may be employed in both multiple queue and multiport memory packet switching nodes employed in computer or telephone communications applications.

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LOAD BALANCING
FOR PACKET SWITCHING NODES

BACKGROUND OF THE DISCLOSURE

The present invention relates generally to packet switching nodes employed in multi-processor and parallel computer systems, and the like, and more particularly to a load balancing circuit arrangement for use in such packet switching nodes which redistributes incoming data packets to its output ports for more efficient processing.

One developing area of computer technology involves the design and development of large-scale, multi-processor-based distributed and parallel computer systems. Typical of these classes of computer systems and architectural approaches are the single instruction stream, multiple data stream (SIMD) computer architecture and the multiple instruction stream, multiple data stream (MIMD) computer architecture.

A SIMD computer typically comprises a control unit, N processors, N memory modules and an interconnection network. The control unit broadcasts instructions to all of the processors, and all active processors execute the same instruction at the same time. Each active processor executes the instruction on data in its own associated memory module. The interconnection network provides a communications facility for the processors and memory modules.

1 A MIMD computer typically comprises N proces-
sors and N memories, and each processor can execute an
independent instruction stream. Each of the processors
may communicate to any other processor. Similar
5 interconnection networks may be employed in the MIMD
computer.

 Various interconnection networks may be
employed to interconnect processors and memories
employed in either type of computer system. These
10 interconnection networks include delta networks, omega
networks, indirect binary n-cube networks, flip net-
works, cube networks and banyan networks, for example.

 The above-cited networks are discussed in some
detail in the following publications: "LSI implementa-
15 tion of modular interconnection networks for MIMD
machines," 1980 Int'l. Conf. Parallel Processing, Aug.
1980, pp. 161-162; "Analysis and simulation of buffered
delta networks," IEEE Trans. Computers, Vol. C-30, pp.
273-282, April 1981; "Processor-memory interconnections
20 for multiprocessors," 6th Annual Int'l. Symp. Computer
Architecture, April 1979, pp. 168-177; "Design and
implementation of the banyan interconnection network in
TRAC," AFIPS 1980 Nat'l. Computer Conf., June 1980, pp.
643-653; "The multistage cube: a versatile interconnec-
25 tion network," Computer, Vol. 14, pp. 65-76, Dec. 1981;
"The hybrid cube network," Distributed Data Acquisi-
tion, Computing and Control Symp., Dec. 1980, pp.
11-22; and "Performance and implementation of 4x4
switching nodes in an interconnection network for
30 PASM," 1981 Int'l Conf. on Parallel Processing, Aug.
1981, pp. 229-233.

 Several types of data switching techniques
may be employed to transfer data in SIMD and MIMD
computers, and the like, including packet switching,
35 message switching, time-division circuit switching or
space-division circuit switching. Packet switching

1 involves sending one or more words of data at time
through the system.

A multiple queue packet switching node is described in a presently copending patent application
5 entitled "Packet Switched Multiple Queue NxM Switch Node and Processing Method," invented by R. J. McMillen, and assigned to the assignee of the present invention. This patent application discloses a packet switching node which processes applied data packets
10 containing routing tag signals indicative of the output port destination to which the data packets are to be applied and transfers these packets to those output ports.

The packet switching node comprises a plurality
15 of input ports and a plurality of output ports. A plurality of queue selectors are individually coupled to corresponding ones of the plurality of input ports. Each of the plurality of queue selectors are adapted to route data packets applied to each of the input ports
20 in accordance with the output port destination of the data packets.

A plurality of queue sets are individually coupled to corresponding ones of the plurality of queue selectors. Each of the queue sets comprise a plurality
25 of queues for storing and forwarding data packets applied thereto as a function of output port destination. A plurality of output arbitrators are individually coupled between corresponding ones of the plurality of output ports and the respective queue of each of
30 the queue sets which store and forward data packets whose destinations are the corresponding output port. The output arbitrators are adapted to transfer the data packets stored in the queues to the corresponding output port in accordance with a predetermined priority
35 arbitration scheme.

1 Another related presently co-pending patent
application is entitled "Packet Switched Multiport
Memory NxM Switch Node and Processing Method," invented
by R. J. McMillen and A. Rosman, and assigned to the
5 assignee of the present invention. This packet switch-
ing node processes applied data packets containing
routing tag signals indicative of the output port
destination to which the data packets are to be ap-
plied. The packet switching node comprises a plurality
10 of input ports and output ports with a multiport memory
coupled therebetween. The memory has a predetermined
number of memory locations available for storage of
data packets applied to each of the input ports.
Control logic is coupled to the input and output ports
15 and the multiport memory which controls the storage of
data packets in the memory. The control logic also
controls the routing of the data packets to the output
ports in accordance with the routing tag signals.

 In general, this invention comprises an N x M
20 switch node that accepts data packets at any of N input
ports and routes each to any of M output ports. The
output selected is determined by the routing tag signal
in the packet. The control logic is designed so that
the data packets are effectively sorted according to
25 their desired output port destination. Arbitration
logic randomly, in a statistical sense, chooses among
any data packets that are directed to the same output
port. The algorithm implemented by the arbitration
logic is designed so that data packets will not wait
30 indefinitely to be routed from the switch node.

 However, although both of these nodes improve
upon the performance and throughput of conventional
packet switching designs, their performance can be
improved. An example will illustrate a typical prob-
35 lem. Assume that processor 1 applies data packets to

1 input port 1. Assume that all output ports of the node
are connected to identical execution units. Processor
1 assigns routing tag signals to each of the data
packets transmitted thereby. If processor 1 continu-
5 ally assigns routing tag signals corresponding to
output port 1, for example, then the remaining output
ports are not used, and the execution units connected
thereto are not used. This clearly lessens the effi-
ciency of the node.

10

SUMMARY OF THE INVENTION

In order to overcome the limitations of prior
art switching node designs, the present invention
provides for a load balancing circuit arrangement that
15 improves the efficiency and performance of existing
packet switching nodes. In general, the load balancing
circuit arrangement of the present invention comprises
a logic circuit for use with a packet switching node
that processes applied data packets that contain
20 routing tag signals indicative of the output port
destinations to which the data packets are addressed.

The load balancing circuit arrangement
comprises a load balancing circuit coupled to the
packet switching node which monitors the output port
25 addresses of the applied data packets. In addition,
the load balancing circuit monitors the number of data
packets addressed to each of the output ports. The
load balancing circuit is adapted to generate new
routing tag signals identifying output port addresses
30 which redistribute the output port load. The load
balancing circuit arrangement includes a tag selection
circuit coupled to the load balancing circuit and the
packet switching node which selectively replaces the
routing tag signals of the applied data packets with

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1 the new routing tag signals in order to redistribute
and balance the output port load.

One embodiment of the present invention
provides for a load balancing circuit arrangement for
5 use with a multiple queue packet switching node that
distributes data packets to the least full queues.
This operation re-routes the data packets to output
ports that are being infrequently used and hence
provides for more efficient processing. A second
10 embodiment of the load balancing circuit is provided
for use with a multiport memory packet switching node.

In the first embodiment, the switching node
comprises queue selection logic coupled to a plurality
of queues which route the applied data packets to the
15 desired output port destinations. The load balancing
circuit arrangement for use with the multiple queue
packet switching embodiment comprises the load balanc-
ing circuit coupled between a plurality of queues and
their associated queue selection logic. The load
20 balancing circuit monitors the number of data packets
stored in each of the queues. The load balancing
circuit is coupled to the tag selection circuit which
provides input signals to the queue selection logic
that replace the routing tag signals of the data packet
25 being processed with new routing tag signals. The new
routing tag signals are representative of the queue
which has the fewest packets stored therein. This
processing redistributes applied data packets to the
least full queue and hence redistributes the output
30 port loading of the circuit.

In the second embodiment, the switching node
comprises a multiport memory and control logic which
similarly route applied data packets to the desired
output ports. The load balancing circuit arrangement
35 for use in the multiport memory packet switching

1 embodiment comprises the load balancing circuit coupled
to the control logic which monitors the number and
destination of the data packets stored in the multiport
memory. The load balancing circuit arrangement pro-
5 vides input signals to the control logic which replace
the routing tag signals with new routing tag signals
which redistribute the applied data packets to the
output ports to achieve balanced output port loading.

The load balancing circuit arrangement
10 comprises a load balancing circuit that monitors the
output port addresses of the applied data packets and
the number of data packets addressed to each of the
output ports. This load balancing circuit generates
the new routing tag signals. A tag selection circuit
15 coupled to the load balancing circuit selectively
applies the new routing tag signals to the switching
node in response to enabling signals applied thereto.

The load balancing circuit comprises a
minimum index circuit for generating the new routing
tag signals and an adder circuit coupled to the minimum
20 index circuit for combining the new routing tag signals
with offset signals which modify the new routing tag
signals in order to implement a predetermined output
port priority scheme.

25 A switching node employing the load balancing
circuit arrangement of the present invention may be
used to construct a multistage interconnection networks
which have several capabilities. The first has the
ability to distribute incoming data packets over a pool
30 of shared resources. These resources are typically
identical execution or memory units connected to the
output ports of the node. The second employs an extra
node stage at the input of the network. Enabling the
load balancing circuit in the switch nodes of the newly
35

1 added stage balances the load throughout the entire
multistage network.

Although the present invention is discussed
with reference to its use with computer systems and
5 architectures, it is not limited to this application.
The present invention may also be used in applications
involving the communications field. In particular,
interconnection networks employing the present inven-
tion may be used to connect telephone systems that
10 communicate both data and voice information by way of
data packets.

BRIEF DESCRIPTION OF THE DRAWINGS

The various objects and features of the
15 present invention may be more readily understood with
reference to the following detailed description taken
in conjunction with the accompanying drawings, wherein
like reference numerals designate like structural
elements, and in which:

20 Fig. 1 illustrates a block diagram of an
embodiment of a load balancing circuit in accordance
with the principles of the present invention incorpo-
rated into one channel of a multiple-queue packet
switching node;

25 Fig. 2 illustrates a more detailed block
diagram of the load balancing circuit of Fig. 1;

Figs. 3a and 3b comprise a detailed schematic
of the logic contained in the minimum index circuit of
the load balancing circuit of Fig. 2;

30 Figs. 4a, 4b and 4c show detailed schematics
illustrating the logic contained in the modulo four
adder of the load balancing circuit of Fig. 2 for three
priority conditions;

1 Figs. 5a and b comprise a detailed block
diagram of a multiport memory packet switching node
without load balancing;

5 Fig. 6 illustrates the load balancing circuit
of the present invention coupled to one channel of the
multiport memory packet switching node of Fig. 5; and

Fig. 7 illustrates a minimum index circuit
for use in the load balancing circuit of Fig. 6.

10 DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Fig. 1, a block diagram of one
embodiment of a load balancing circuit arrangement 20
in accordance with the principles of the present
invention is shown. The load balancing circuit ar-
15 rangement 20 is shown incorporated into one channel of
a multiple queue packet switching node 21. This load
balancing circuit arrangement 20 is made part of a
single stage packet switching node 21. The packet
switching node 21 processes applied data packets
20 containing routing tag signals indicative of the output
port destination to which the data packets are ad-
dressed.

One channel of the packet switching node 21
comprises an input port 22 and a plurality of output
25 ports 26. A queue set 23 is coupled to the input port
22. The queue set 23 comprises a plurality of queues
which individually process and store data packets whose
destinations are a particular one of the output ports
26. A queue selector 24 is coupled between the input
30 port 22 and each of the plurality of queues in the
queue set 23. The queue selector 24 is adapted to
route applied data packets arriving at the input port
22 to corresponding ones of the queues in accordance
with the addresses contained in the routing tag sig-
35 nals.

1 An output arbitrator 25 is coupled between
each output port and respective queues of the queue
set. The output arbitrator 25 processes data packets
whose destinations are the output port coupled thereto
5 and applies the data packets stored in each of the
respective queues to that output port in accordance
with a predetermined priority arbitration scheme.

 A more detailed description of the basic
multiple queue packet switching node 21 is provided in
10 the presently copending application entitled "Packet
Switched Multiple Queue NxM Switch Node and Processing
Method," cited hereinabove. This patent application is
incorporated herein by this reference.

 The load balancing circuit arrangement 20 is
15 coupled between each of the queues of the queue set 23
and the queue selector 24. The load balancing circuit
arrangement 20 monitors the number of data packets
stored in each of the queues. The load balancing
circuit arrangement 20 provides input signals to the
20 queue selector 24 which replace the routing tag signals
of the data packets currently being processed. These
input signals are representative of the queue in the
queue set 23 which has the fewest packets stored
therein.

25 The load balancing circuit arrangement 20
comprises a load balancing circuit 28 coupled to the
queues 23 of the packet switching node 20. The load
balancing circuit 28 monitors the number of data
packets addressed to each of the output ports 26 by
30 examining the number of packets in the queue 23 associ-
ated with each output port 26. The load balancing
circuit 28 is adapted to generate new routing tag
signals identifying output port addresses which redis-
tribute the output port load. A tag selection circuit
35 27 is coupled between the load balancing circuit 28 and

1 the queue selector 24 which is adapted to selectively
replace the routing tag signals of the applied data
packets with the new routing tag signals in order to
redistribute and balance the output port load.

5 The load balancing circuit 28 may comprise a
minimum index circuit coupled to an adder circuit. The
minimum index circuit is adapted to generate the new
routing tag signals and the adder circuit is adapted to
combine the new routing tag signals with offset signals
10 which modify the new routing tag signals in order to
implement a predetermined output port priority scheme.
These two circuits will be described in more detail
with reference to Fig. 2. The tag selection circuit 27
may comprise a two to one multiplexer, or the like,
15 which is adapted to selectively choose between two
input signals for output to the queue selector 24.

In operation, the multiple queue packet
switching node 21 employing the load balancing circuit
arrangement 20 functions in the following manner. In a
20 typical multi-processor computer application requiring
load balancing, or the like, a process controller, or
the like, is coupled to the input port 22. This
process controller generates data and instructions
which are sent to functionally identical execution
25 units individually coupled to the output ports 26. The
data and instructions are sent in data packets which
are processed by the packet switching node 21. The
switching node 21 provides a communications link
between the process controller and the execution units.

30 Each data packet includes a routing tag
signal identifying the particular output port 26, and
hence the particular execution unit, to which the
packet is to be sent. In addition, the data packet
also includes data that is to be operated upon in that
35 execution unit. A data packet enters the switching

1 node 21 and the queue selector 22 reads the routing tag
signal. It then routes the data packet to the appro-
2 priate queue of the queue set 23 which processes
signals whose destinations are the particular output
5 port 26 corresponding to the routing tag signal.

In the multi-processor computer of this
example, each of the output ports are connected to
functionally identical execution units. Therefore, it
is not particularly important where the instructions
10 contained in the data packets get executed, but that
they are executed in a timely manner. Since all of the
execution units are functionally identical, routing tag
signals may be changed in order to more efficiently
utilize the execution units.

15 The load balancing circuit arrangement 20
produces the desired re-routing of the data packets to
accomplish more efficient operation of the switching
node 21 and the computer system in general. The load
balancing circuit 20 processes count signals generated
20 by each of the queues 23 in the queue set 24. The
count signals indicate the number of data packets
stored in a particular queue. The load balancing
circuit arrangement 20 then analyzes the count signals
to determine which queue has the least number of data
25 packets stored therein. Once this has been determined,
the routing tag signal in the data packet being pro-
cessed by the queue selection logic 23 is changed to
identify the least full queue.

To better understand the operation of the
30 load balancing circuit 20, reference is made to Fig. 2.
Fig. 2 shows a more detailed block diagram of the load
balancing circuit 28. The load balancing circuit 28 is
comprised of the minimum index circuit 30 and an adder
circuit 31. In Fig. 2, the load balancing circuit 28-
35 is shown adapted for use with a node which comprises

1 four output ports, hence it employs four sets of inputs
to the minimum index circuit 30, identified as L[0] to
L[3].

Each set of inputs to the minimum index
5 circuit 30 is individually coupled to count circuitry
in the queues which counts the number of data packets
currently being stored and processed by a particular
queue. The output of the minimum index circuit 30 is
coupled to a modulo M adder 31 (modulo 4 in Fig. 2)
10 which adds an offset to the index produced. The load
balancing circuit 28 implements an algorithm which
determines the least full queue in the queue set. A
typical algorithm is presented below.

```
1.  INPUT SCALAR:  OFFSET
15  2.  INPUT ARRAY:  L[M]
    3.  OUTPUT SCALAR: ADDR
    4.  BEGIN
    5.      minimum:=0;
    6.      FOR (i=1; WHILE i<M; i:=i+1)
20  7.          IF (L[i] < L[minimum])
    8.              minimum:=i;
    9.      ENDFOR
   10.      ADDR: = (minimum + OFFSET) MODULO M;
   11.  END
```

25 This algorithm scans the inputs L[M] from low
order to high, looking for the smallest value. In the
case of a tie, the value is retained, thus implementing
a particular priority scheme. This priority scheme is
as follows. Since there can be a tie between two or
30 more queues for the lowest number, a default priority
is assigned. Let L[0] be the first input to the
minimum index circuit 30 and let L[M-1] be the last
input. In the case of a tie, L[0] has the highest
priority and L[M-1] has the lowest.

35

1 Alternatively, if the first queue is not to
have the highest priority, rather queue i , $0 < i < M$, then
the queue i data packet count is connected to $L[0]$, the
queue with the next highest priority is connected to
5 $L[1]$, and so on. In addition, in order to obtain the
correct re-routing tag signal, the binary representa-
tion of i is connected to the OFFSET input to the
modulo M adder 31. To convert this algorithm into a
logic circuit requires the specification of the maximum
10 queue size and the number of output ports (M), in order
to determine the number of input and output bits in the
load balancing circuit 28.

 The ability to specify priority is important.
In an $N \times M$ packet switching node, for example, N of the
15 load balancing circuits are required. If all circuits
gave top priority to the lower numbered outputs, there
would be a bias in the overall operation of of the
switching node favoring these outputs. The distribu-
tion of the load over the outputs would not be uniform.

20 To illustrate how the load balancing circuit
28 is reduced to logic, assume a four by four packet
switching node with queues that can hold up to three
data packets. Therefore, the number of input ports $N =$
4 and the number of output ports $M = 4$, and the number
25 of data packets $P = 3$. The equation $\lceil \log_2(P+1) \rceil =$
 $\lceil \log_2(3+1) \rceil = 2$ represents the number of bits required
to indicate the data packet count in any queue. Since
there are four queues, a total of eight inputs are
needed for the minimum index circuit 30. Also, $\lceil \log_2 M \rceil$
30 $= 2$ bits are required to indicate the which queue is to
be selected. Therefore, each input to the minimum
index circuit 30, represented by $L[i]$, is represented
by two bits, L_{i1} and L_{i0} , and ADDR and OFFSET are
represented by two bits each, $ADDR_1$, $ADDR_0$, and OFF-
35 SET $_1$, $OFFSET_0$, respectively.

15

1 The load balancing circuit 28 comprises two
parts, the minimum index circuit 30 and the modulo four
adder 31 which combines the output of the minimum index
circuit 30 with the OFFSET value. A modified algorithm
5 is required to implement the minimum index circuit
only, and is presented below.

```

1.  INPUT ARRAY:  L[M]
2.  OUTPUT SCALAR: OUT
3.  BEGIN
10  4.      minimum:=0;
5.      FOR (i=1; WHILE i<M; i:=i+1)
6.      IF (L[i] < L[minimum])
7.      minimum:=i;
8.      ENDFOR
15  9.      OUT:=minimum;
10. END

```

20 This algorithm has been programmed into a
computer to generate a truth table with eight boolean
input variables and two boolean output variables. This
truth table was then made the input to a program which
generated the following "sum-of-product" form logic
equations. These equations correspond directly to a
two level nand gate implementation of the minimum index
circuit 30.

```

25  OUT1 =  $\overline{L31} \cdot \overline{L30} \cdot L10 \cdot L00 + \overline{L21} \cdot \overline{L20} \cdot L10 \cdot L01$ 
      +  $\overline{L21} \cdot \overline{L20} \cdot L11 \cdot L00 + \overline{L31} \cdot L11 \cdot L01$ 
      +  $\overline{L31} \cdot \overline{L30} \cdot L10 \cdot L01 + \overline{L31} \cdot \overline{L30} \cdot L11 \cdot L00$ 
      +  $\overline{L21} \cdot \overline{L20} \cdot L10 \cdot L00 + \overline{L21} \cdot L11 \cdot L01$ 
      +  $\overline{L30} \cdot L11 \cdot L10 \cdot L01 \cdot L00$ 
30  +  $\overline{L20} \cdot L11 \cdot L10 \cdot L01 \cdot L00$ 
      OUT0 =  $\overline{L11} \cdot \overline{L10} \cdot L00 + \overline{L11} \cdot \overline{L10} \cdot L01$ 
      +  $\overline{L31} \cdot \overline{L30} \cdot L20 \cdot L00 + L20 \cdot \overline{L11} \cdot L01$ 
      +  $\overline{L31} \cdot \overline{L30} \cdot L20 \cdot L01 + \overline{L31} \cdot \overline{L30} \cdot L21 \cdot L00$ 
      +  $\overline{L31} \cdot L21 \cdot L01 + L21 \cdot \overline{L11} \cdot L01$ 
35  +  $L21 \cdot \overline{L10} \cdot L01 \cdot L00 + \overline{L30} \cdot L21 \cdot L20 \cdot L01 \cdot L00$ 

```

1 A detailed schematic of the logic diagram
 representing a specific embodiment of the minimum index
 circuit 30 is shown in Fig. 3. Fig. 3 is comprised of
 Figs. 3a and 3b. Figs. 3a and 3b should be placed
 5 abutting one another and joined along the line of
 separation in order to obtain the complete drawing.

The "sum-of-product" form of the equations
 for the modulo four adder 31 are as follows.

$$C1 = B1 \cdot \overline{A1} \cdot \overline{A0} + B1 \cdot \overline{B0} \cdot \overline{A1} + \overline{B1} \cdot \overline{B0} \cdot A1$$

$$10 \quad + \overline{B1} \cdot A1 \cdot \overline{A0} + \overline{B1} \cdot B0 \cdot \overline{A1} \cdot A0 + B1 \cdot B0 \cdot A1 \cdot A0$$

$$C0 = B0 \cdot \overline{A0} + \overline{B0} \cdot A0 = B \oplus A$$

Since the B input is the OFFSET constant, once the
 constant is selected, it is substituted into the above
 equations which results in simpler circuits. If the
 15 OFFSET = 0, no circuit is required. Figs. 4a, 4b and
 4c show the circuits to be used when the OFFSET is 1, 2
 and 3, respectively. A detailed discussion of the
 components and wiring of the circuit of Figs. 3 and 4
 will be dispensed with.

20 The load balancing circuit arrangement of the
 present invention may also be incorporated into a
 multiport memory packet switching node. Fig. 5 illus-
 trates a portion of a four input, four output multiport
 memory packet switching node without load balancing.

25 This circuit is identical to the circuit of Fig. 3 of
 the presently copending multiport memory patent appli-
 cation cited hereinabove. Fig. 5 shows control logic
 40 of the multiport memory packet switching node. The
 control logic comprises four input port logic sections
 41a-d coupled to four output port logic sections 42a-d.
 30 In addition, handshaking signal lines 45 and status
 update control logic 46 are included in Fig. 5.

Referring to Fig. 6, there is shown a portion
 of one channel of the multiport memory packet switching

1 node of Fig. 5 incorporating a load balancing circuit
arrangement 20' of the present invention. The discus-
sion of this embodiment is undertaken with reference to
the presently copending patent application entitled
5 "Packet Switched Multiport Memory NxM Switch Node and
Processing Method" cited hereinabove with particular
reference to Fig. 3 thereof.

Fig. 6 shows a portion of the control logic
40 which includes an input port logic section 41a
10 coupled to four output port logic sections 42a-d. A
more detailed understanding of the complete circuit
will be had with reference to Fig. 3 in the previously
cited patent application. The signal lines illustrated
in Fig. 6 of this application correspond to signal
15 lines described in Fig. 3 of the copending patent
application.

The load balancing circuit arrangement 20'
has inputs coupled to request output lines REQ0, REQ1,
REQ2 and REQ3 of the input port logic section 41.
20 Outputs of the load balancing circuit arrangement 20'
are coupled to a latch 45 which is used to ensure
correct signal timing and then to the enabling circuit
27. A load balancing circuit 28' comprises a minimum
index circuit 30' and the adder 31. The minimum index
25 circuit 30' for use in this embodiment is shown in more
detail in Fig. 7. The adder circuit 31 is substantial-
ly the same as hereinabove described with reference to
the load balancing circuit arrangement for the multiple
queue node.

30 Thus, there has been described a load balanc-
ing circuit for use with a packet switching node which
may be employed in multi-processor and parallel comput-
er systems, and the like. The load balancing circuit
may be used to automatically redistribute data packets
35 to external execution units coupled to a multiple queue

1 or multiport memory switching node. This redistribu-
tion results in more efficient operation of the node
and computer system employing networks incorporating
the load balancing circuit.

5 It is to be understood that the above-
described embodiments are merely illustrative of some
of the many specific embodiments which represent
applications of the principles of the present inven-
tion. Clearly, numerous and varied other arrangements
10 may be readily devised by those skilled in the art
without departing from the spirit and scope of the
invention. In particular, the present invention may
also be used in applications involving the communi-
cations field. Interconnection networks employing the
15 principles of the present invention may be used to
connect telephone systems that communicate both data
and voice information by way of data packets.

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CLAIMSWhat is claimed is:

- 1 1. A load balancing circuit arrangement for
use with a packet switching node that processes applied
data packets that contain routing tag signals indica-
5 tive of the output port destinations to which said data
packets are addressed, wherein said load balancing
arrangement comprises:

 load balancing means coupled to said packet
switching node for monitoring the output port addresses
of said applied data packets and the number of data
10 packets addressed to each of said output ports, and for
generating new routing tag signals identifying output
port addresses which are adapted to redistribute the
output port load; and

 tag selection means coupled to said load
15 balancing means and said packet switching node for
selectively replacing the routing tag signals of said
applied data packets with said new routing tag signals
in order to redistribute and balance the output port
load.

- 1 2. The load balancing circuit arrangement
of Claim 1 wherein:

 said load balancing means comprises a logic
circuit which monitors the output port addresses of
5 said applied data packets and the number of data
packets addressed to each of said output ports, and
generates said new routing tag signals; and

 said tag selection means comprises a logic
circuit for selectively applying said new routing tag
10 signals to said switching node in response to enabling
signals applied thereto.

1 3. The load balancing circuit arrangement
of Claim 2 wherein said load balancing means comprises:
a minimum index circuit for generating said
new routing tag signals; and

5 an adder circuit coupled to said minimum
index circuit for combining said new routing tag
signals with offset signals which modify said new
routing tag signals in order to implement a predeter-
mined output port priority scheme.

1 4. A load balancing circuit arrangement for
use with a switching node that processes applied data
packets containing routing tag signals indicative of
the output port destinations to which said data packets
5 are addressed, and wherein said switching node compris-
es a multiport memory and control logic coupled thereto
for routing applied data packets in accordance with the
output port destination thereof, wherein said load
balancing circuit arrangement comprises:

10 load balancing means coupled to said control
logic for monitoring the output port addresses of said
applied data packets and the number of data packets
addressed to each of said output ports, and for gener-
ating new routing tag signals identifying output port
15 addresses which are adapted to redistribute the output
port load; and

20 tag selection means coupled to said load
balancing means and said control logic for selectively
replacing the routing tag signals of said applied data
packets with said new routing tag signals in order to
redistribute and balance the output port load.

1 5. The load balancing circuit arrangement
of Claim 4 wherein:

5 said load balancing means comprises a logic circuit which monitors the output port addresses of said applied data packets and the number of data packets addressed to each of said output ports, and generates said new routing tag signals; and

10 said tag selection means comprises a logic circuit for selectively applying said new routing tag signals to said switching node in response to enabling signals applied thereto.

1 6. The load balancing arrangement of Claim 5 wherein said load balancing means comprises:

 a minimum index circuit for generating said new routing tag signals; and

5 an adder circuit coupled to said minimum index circuit for combining said new routing tag signals with offset signals which modify said new routing tag signals in order to implement a predetermined output port priority scheme.

1 7. A load balancing circuit arrangement for use with a packet switching node that processes applied data packets containing routing tag signals indicative of the output port destinations to which said data packets are addressed, and wherein said switching node comprises queue selection logic coupled to a plurality of queues for routing applied data packets in accordance with the output port destination thereof, wherein said load balancing circuit arrangement comprises:

10 load balancing means coupled to said plurality of queues for monitoring the number of data packets addressed to each of said output ports, and for generating new routing tag signals identifying output port addresses which are adapted to redistribute the output port load; and

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20 tag selection means coupled to said load
balancing means and said queue selection logic for
selectively replacing the routing tag signals of said
applied data packets with said new routing tag signals
in order to redistribute and balance the output port
load.

1 8. The load balancing circuit arrangement
of Claim 7 wherein:

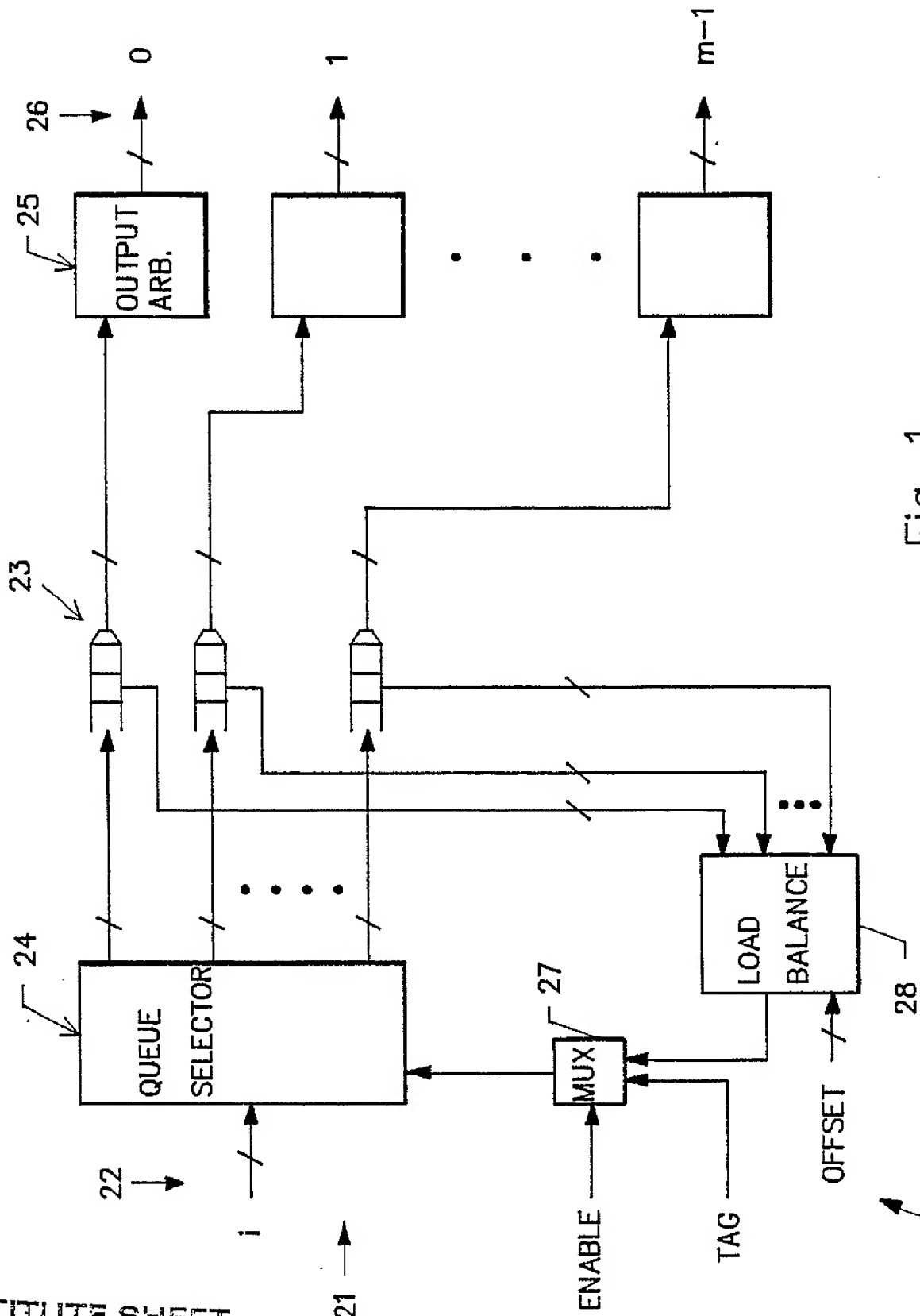
5 said load balancing means comprises a logic
circuit which monitors the output port addresses of
said applied data packets and the number of data
packets addressed to each of said output ports, and
generates said new routing tag signals; and

10 said tag selection means comprises a logic
circuit for selectively applying said new routing tag
signals to said switching node in response to enabling
signals applied thereto.

1 9. The load balancing circuit arrangement
of Claim 8 wherein said load balancing means comprises:

a minimum index circuit for generating said
new routing tag signals; and

5 an adder circuit coupled to said minimum
index circuit for combining said new routing tag
signals with offset signals which modify said new
routing tag signals in order to implement a predeter-
mined output port priority scheme.



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Fig. 2

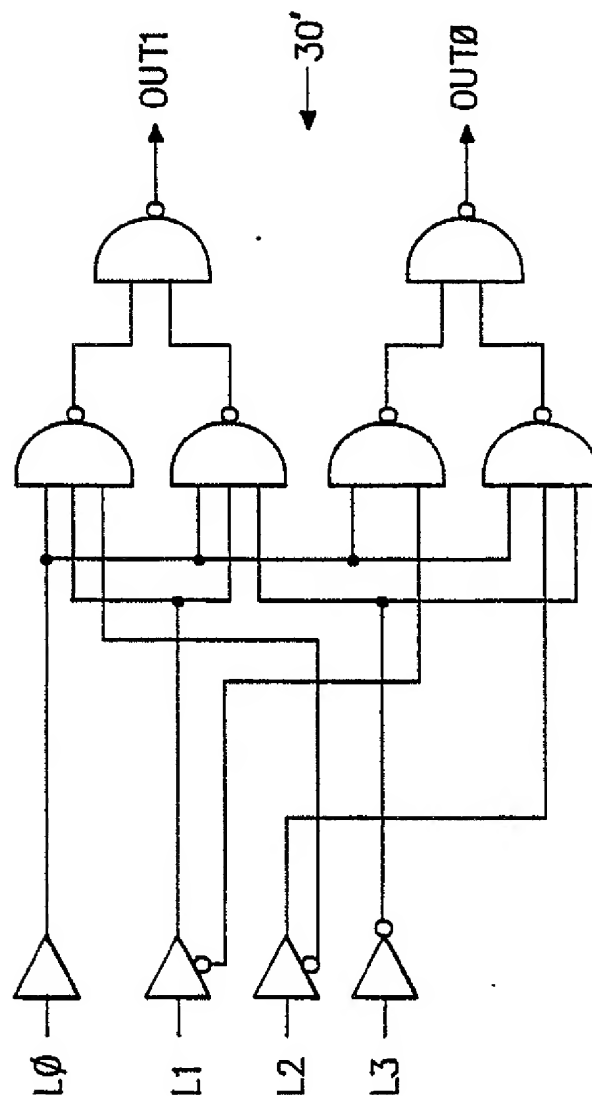
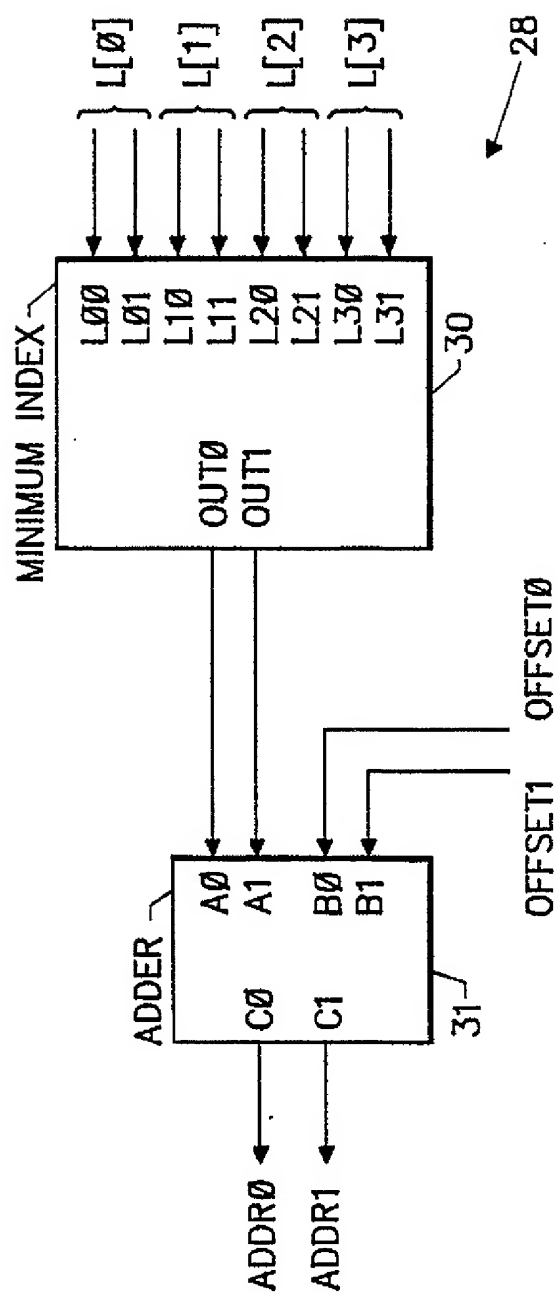
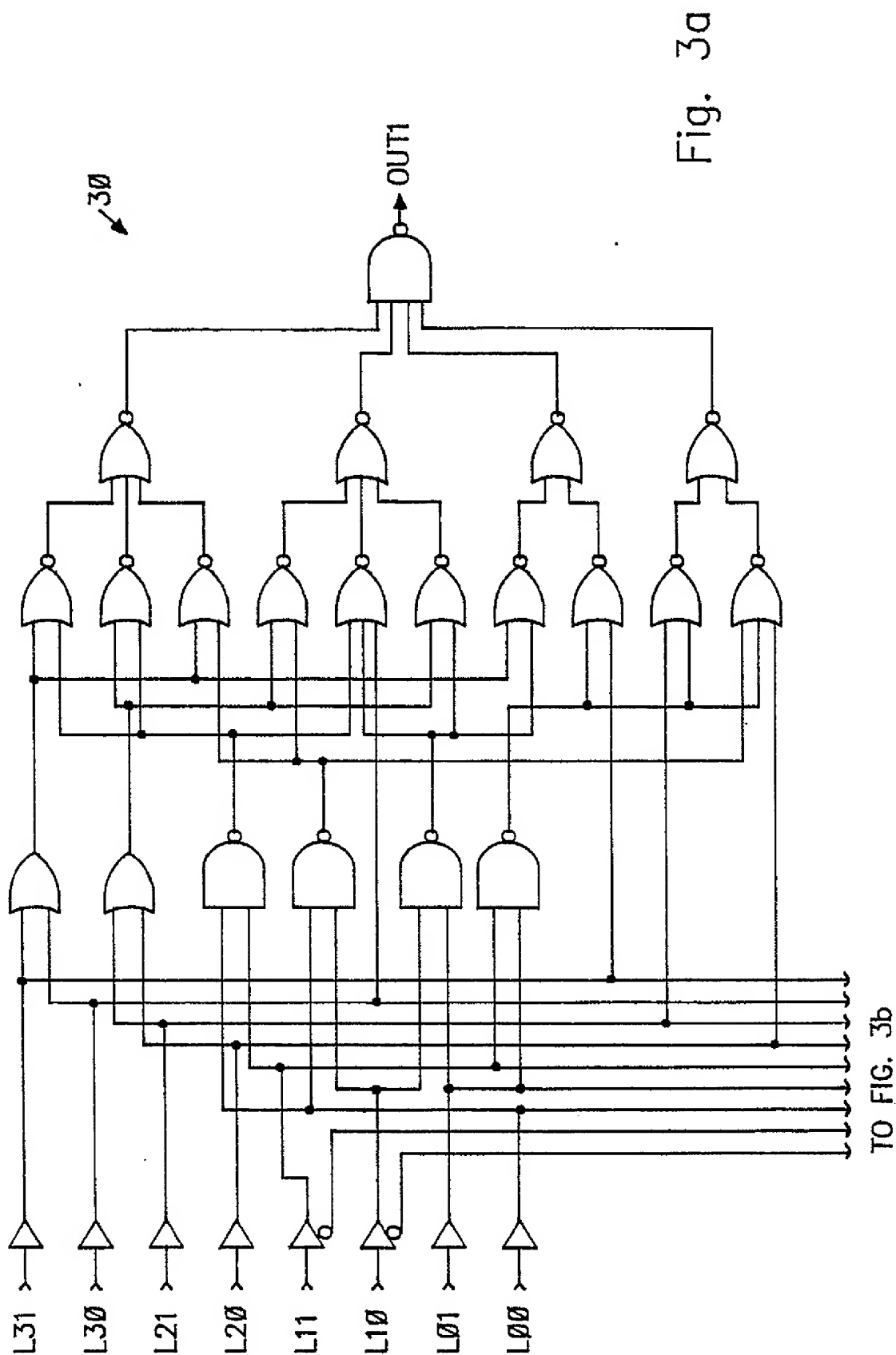


Fig. 7

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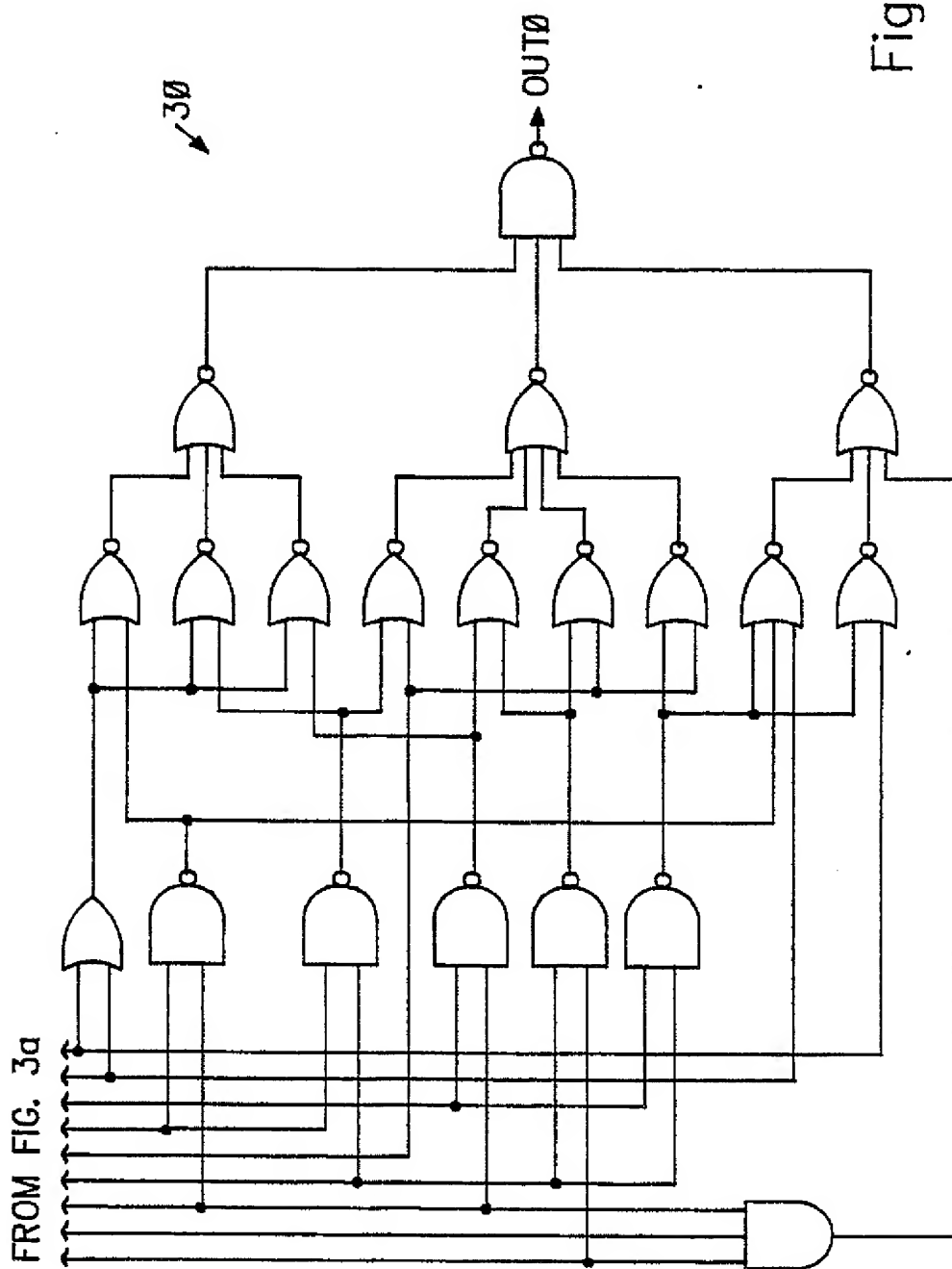


Fig. 3b

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Fig. 4a

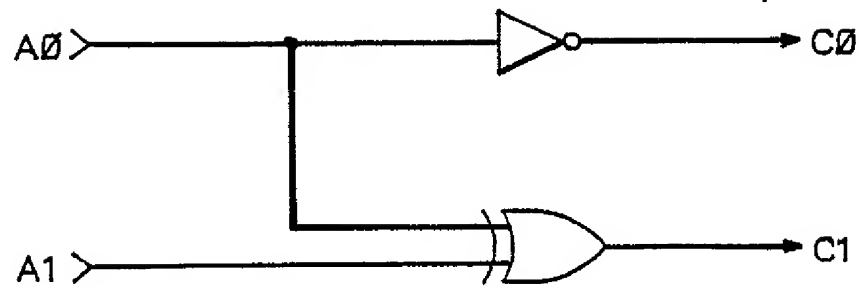


Fig. 4b

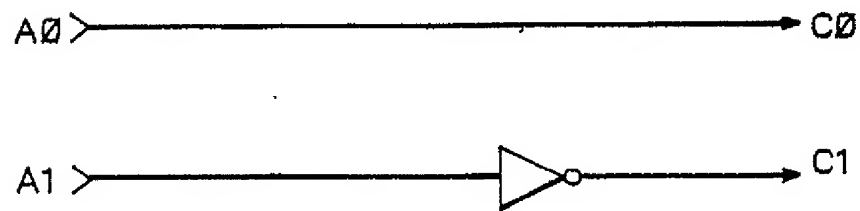
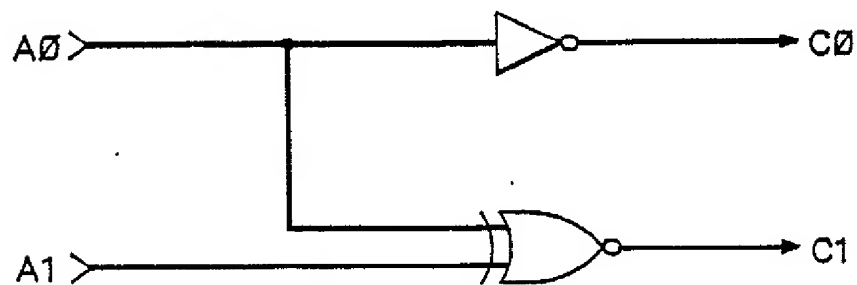


Fig. 4c



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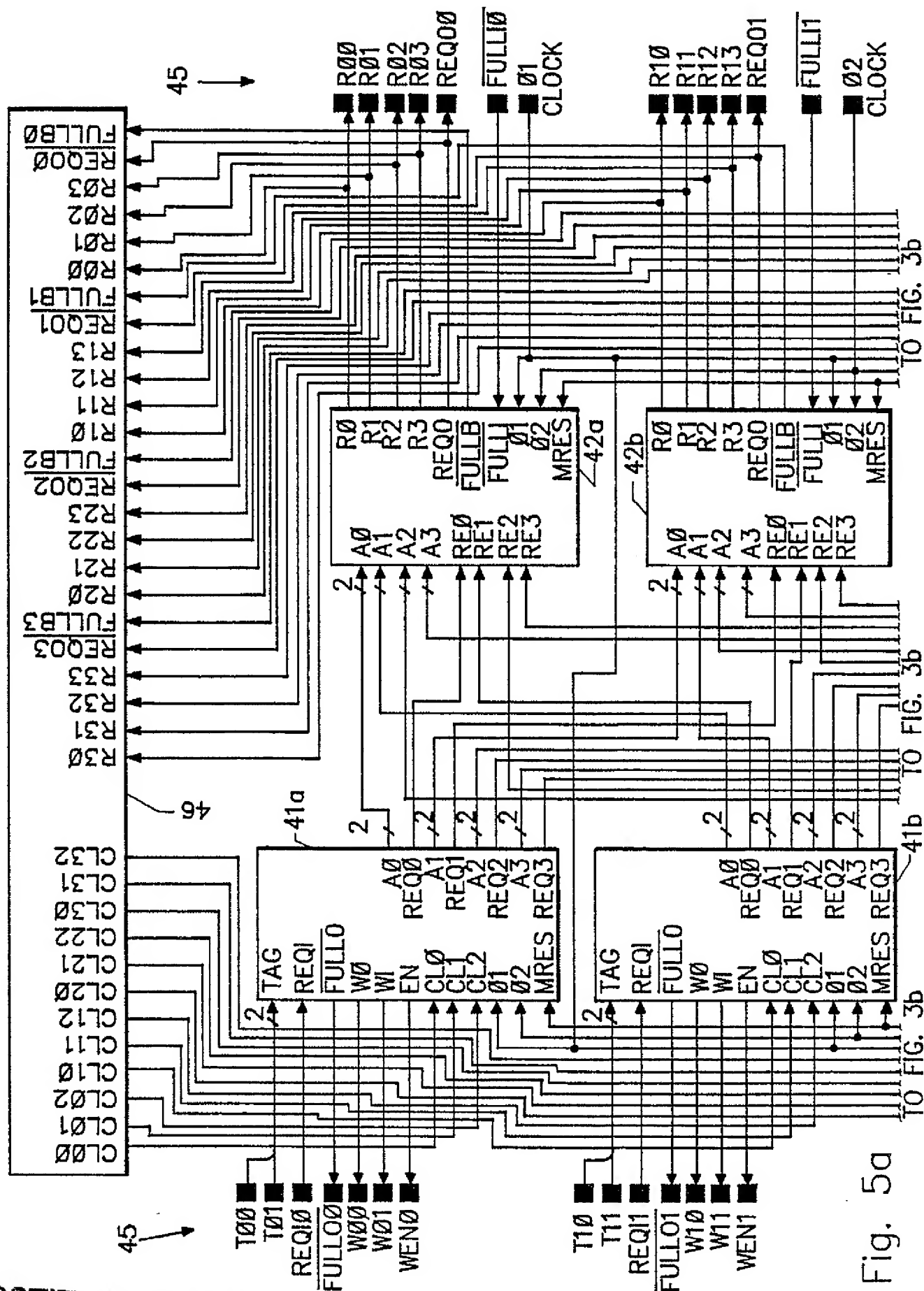
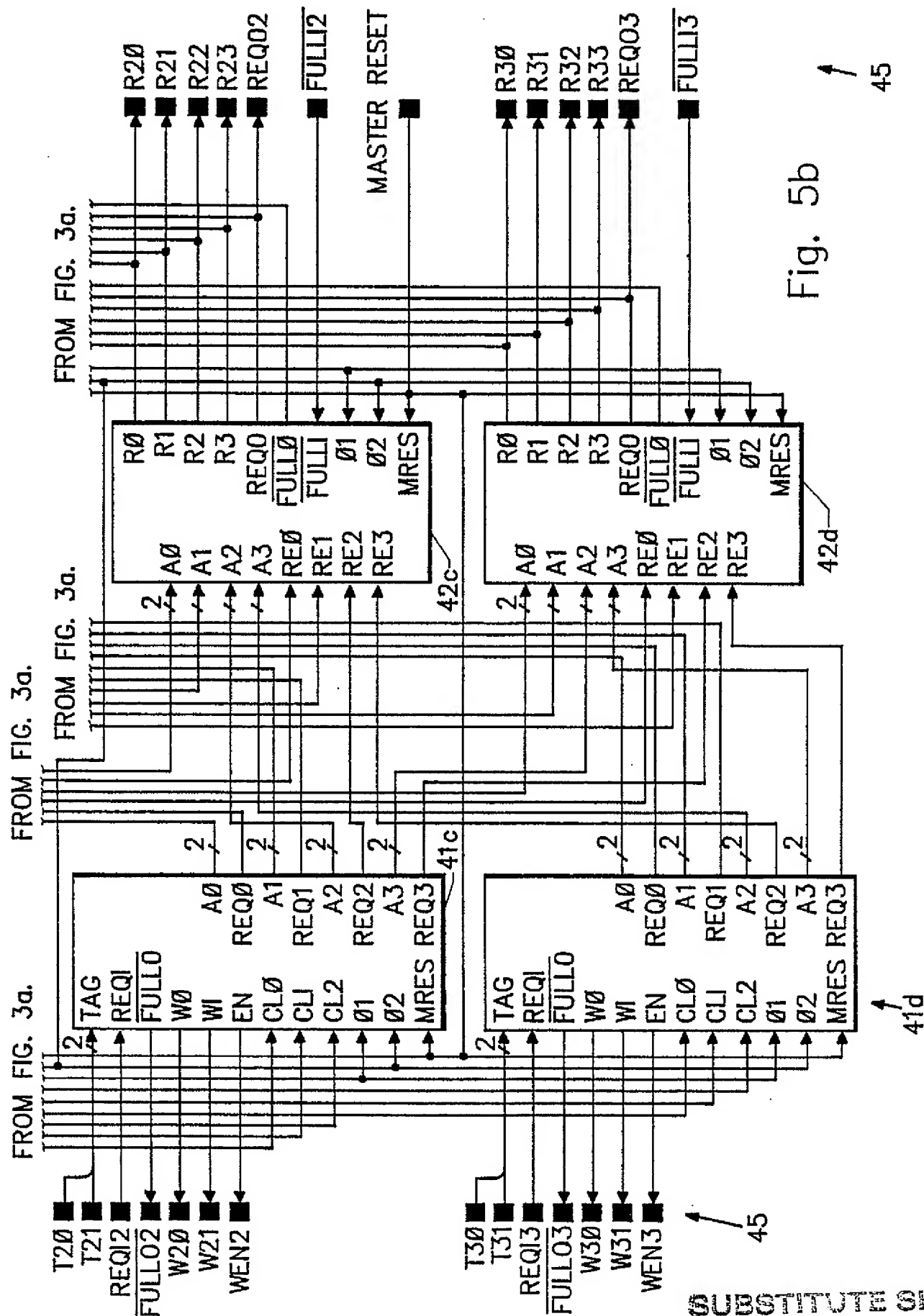
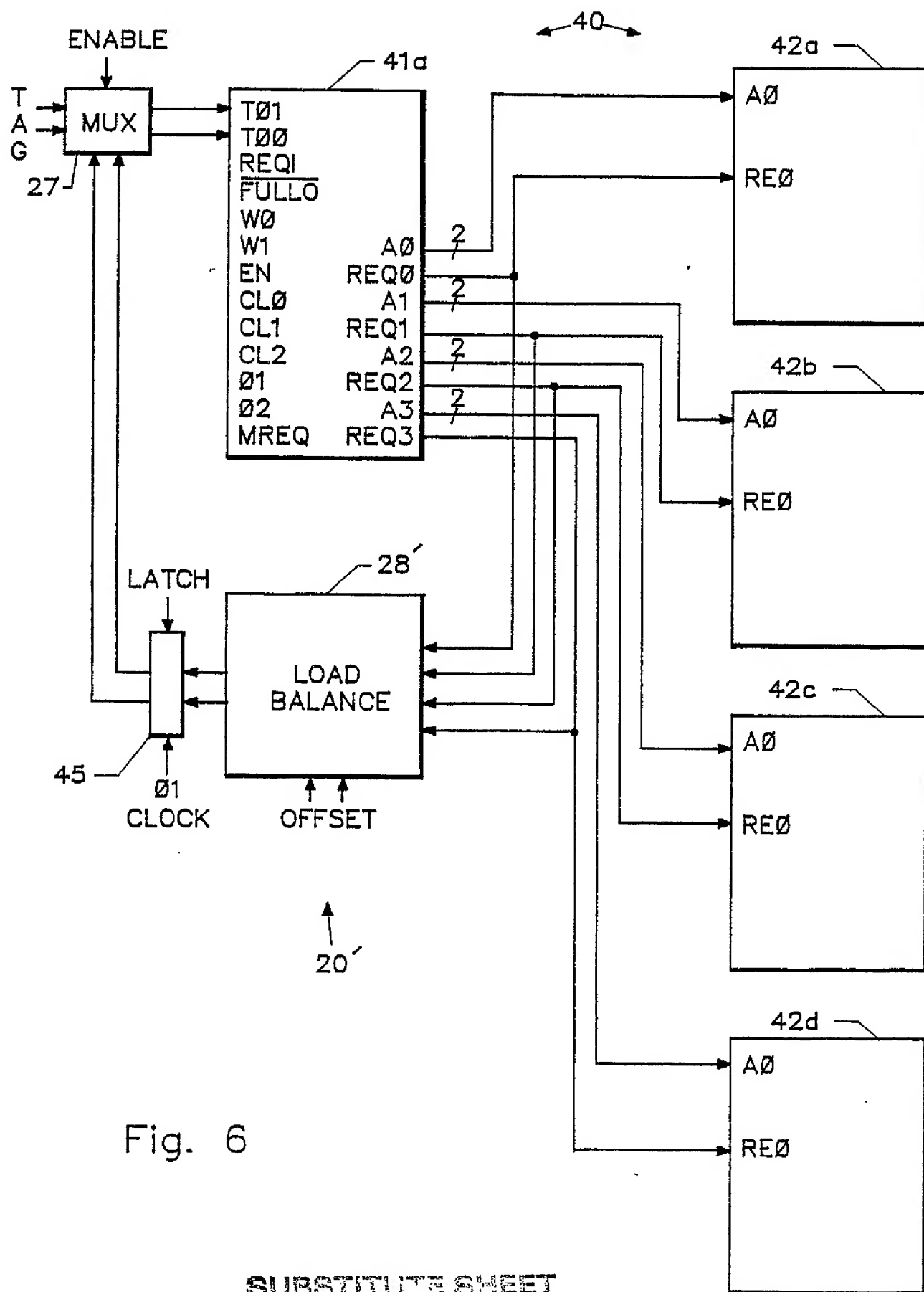


Fig. 5a

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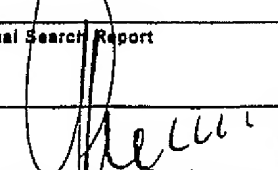


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INTERNATIONAL SEARCH REPORT

International Application No PCT/US 85/01839

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC IPC ⁴ : H 04 L 11/20; G 06 F 15/16		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC ⁴	H 04 L 11/20; G 06 F 15/16; G 06 F 13/14	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹		
Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
P, Y	Patents Abstracts of Japan, vol. 8, no. 264 (E-282) (1701), 4 December 1984 & JP, A, 59135953 (FUJITSU) 4 August 1984 see the whole document	1-9
--		
Y	Proceedings of the International Teletraffic Congress, Stockholm, 13-20 June 1973, Proc. 7, Part 2, Swedish Communications 1973 (Stockholm, SW) Herzog: "Message-switching networks with alternate routing", pages 415/1-415/8, see paragraph 2.1 "Structure and operating made of data switching centers" and figure 2 of page 415/2	1-9
--		
Y	WO, A, 84/01077 (WILSON) 15 March 1984 see page 17, lines 1-17	1-9
--		
Y	Conference Proceedings: the 9th annual symposium on computer architecture,	./.
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>¹⁰ Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p> </div> </div>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search 19th December 1985	Date of Mailing of this International Search Report 24 JAN. 1986	
International Searching Authority EUROPEAN PATENT OFFICE	Signature of Authorized Officer <div style="text-align: right;">  G.L.M. Bruydenberg </div>	

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
	26-29 April 1982 (Austin, US) Parker et al.: "The gamma network: a multiprocessor interconnection network with redundant paths", pages 73-80, see page 74, right-hand column, lines 11-47; figure 1 -----	1-9

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/US 85/01839 (SA 10913)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 17/01/86

The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A- 8401077	15/03/84	EP-A- 0104802	04/04/84
		US-A- 4482996	13/11/84

For more details about this annex :
see Official Journal of the European Patent Office, No. 12/82

